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In this chapter you will discover...

- the structure of our Milky Way Galaxy and Earth's location in it
- how galaxies are categorized by their shapes
- that galaxies are found in clusters that contain huge amounts of dark matter and why clusters of galaxies form in superclusters
- that the universe is expanding

2

Schematic Diagrams of the Milky Way

3

Our Galaxy

This wide-angle photograph spans half the Milky Way. The Northern Cross is at the left and the Southern Cross is at the right. The center of the Galaxy is in the constellation Sagittarius, in the middle of this photograph. The dark lines and blotches are caused by hundreds of interstellar clouds of gas and dust that obscure the light from background stars, rather than by a lack of stars.

4

Electron Spin and the Hydrogen Atom

Parallel spins: higher-energy configuration

Opposite spins: lower-energy configuration

Photon, wavelength = 21 cm

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Mapping the spiral structure of the Galaxy

Everything rotating in same direction.

A has greatest angular speed and moving fastest away from sun. A has higher density of H, B & C moving at about same angular speed \rightarrow sun's angular speed. D is outside solar distance \rightarrow slower angular speed and has less material (density).

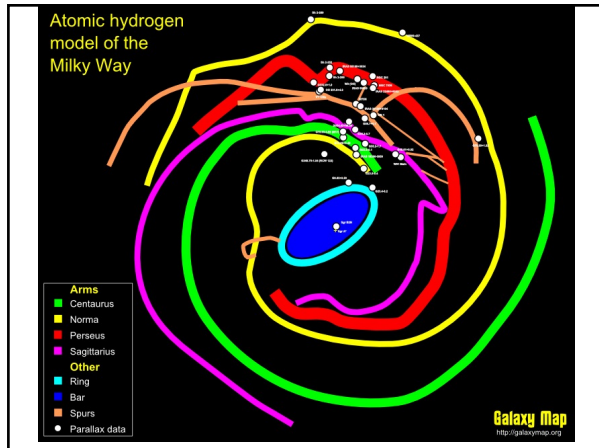
Intensity

Radial velocity (km/sec)

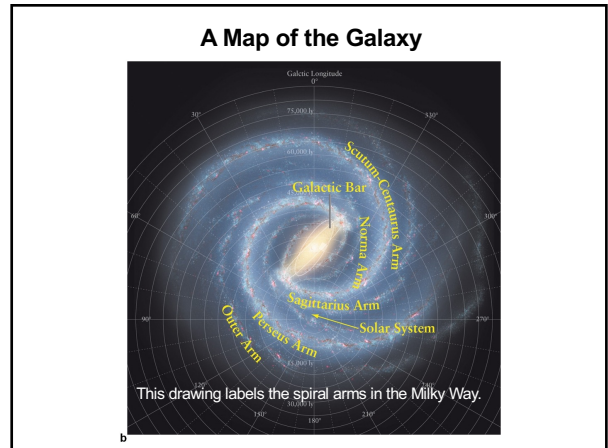
Four clouds all in the same direction. Use doppler shifts to distinguish one cloud from the other. Use the rotation curve to convert the doppler shifts of each cloud to distances from the center of the Galaxy. Do this for other directions to build up a map of the Galaxy strip by strip.

Spiral structure of Galaxy

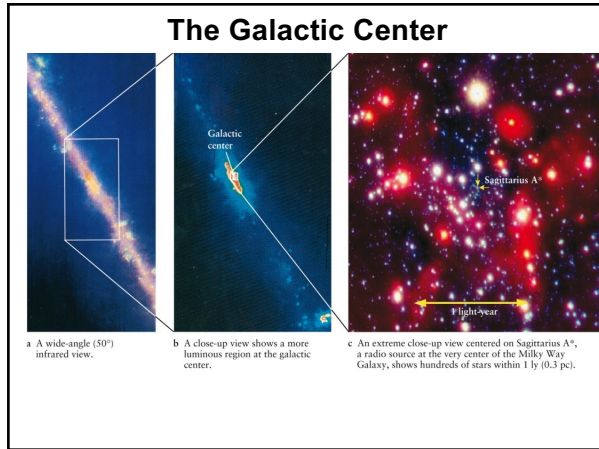
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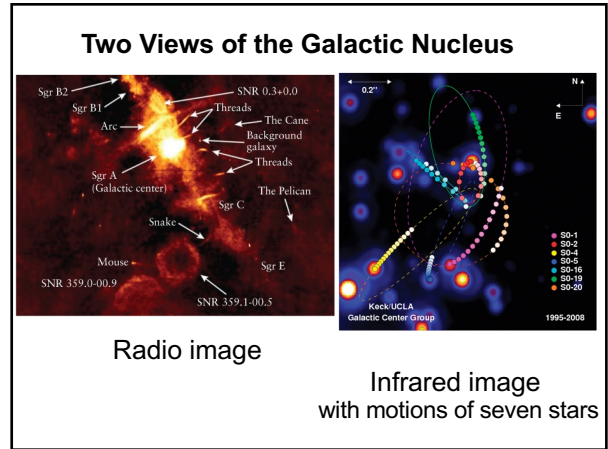
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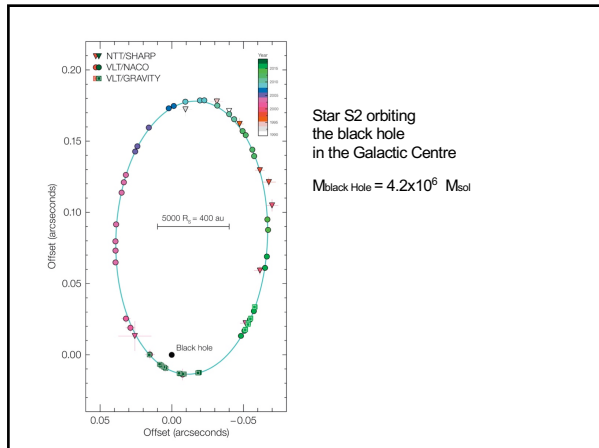
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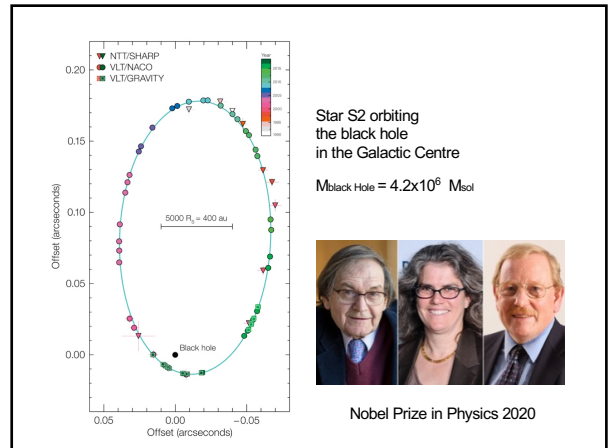
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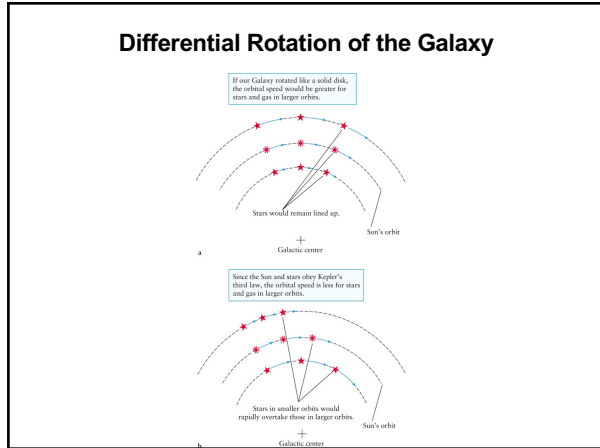
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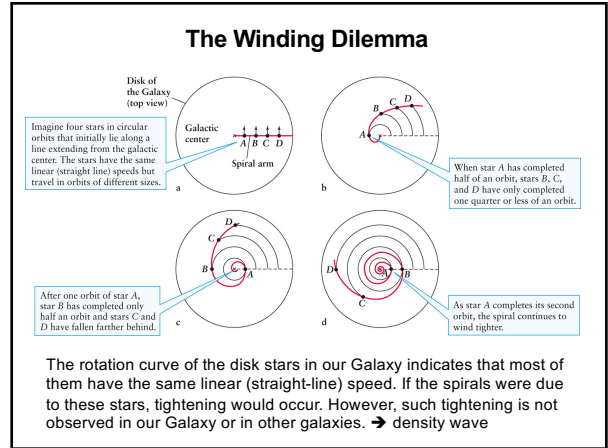
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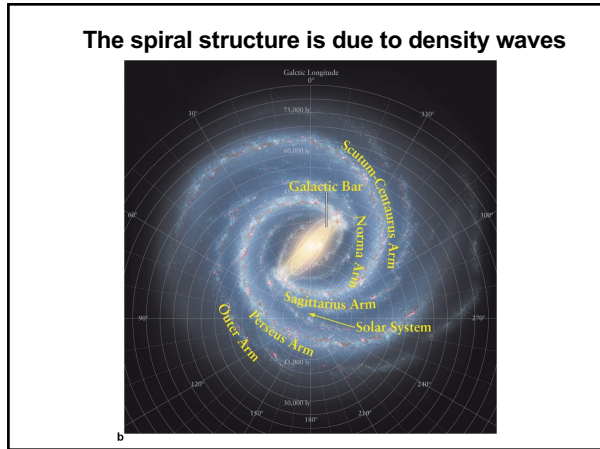
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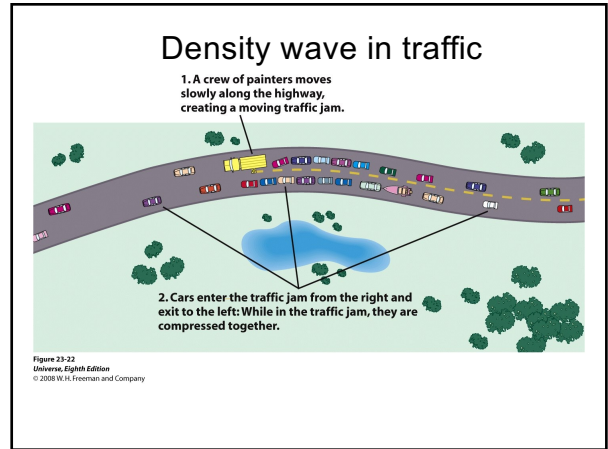
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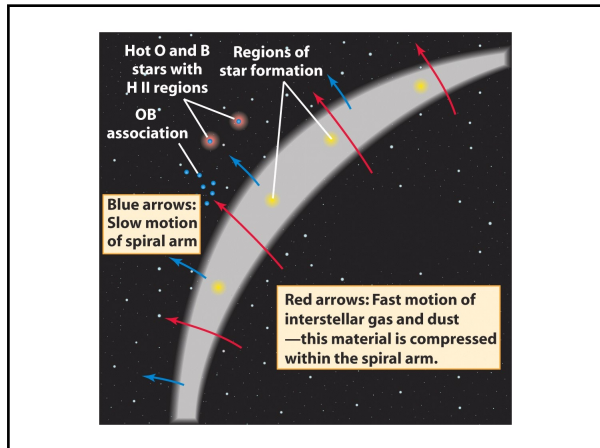
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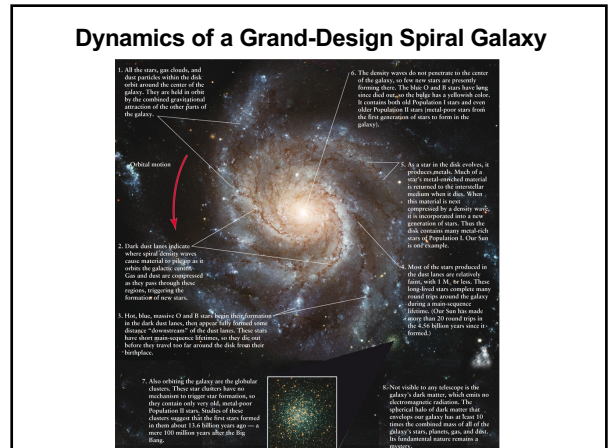
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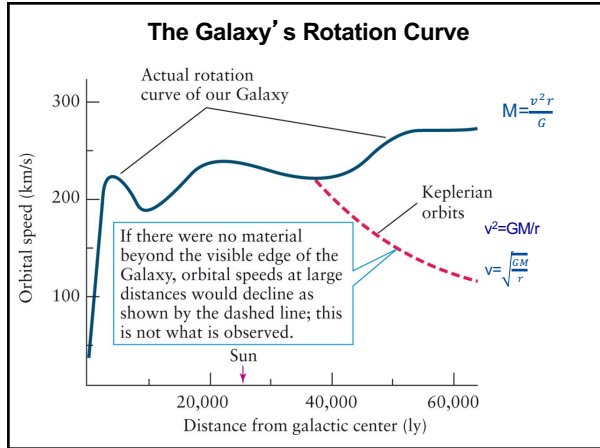
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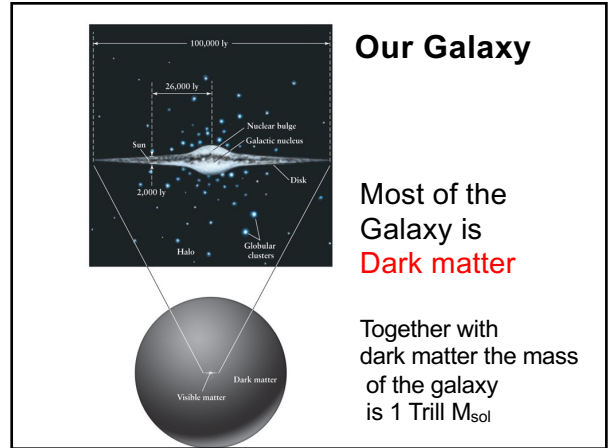
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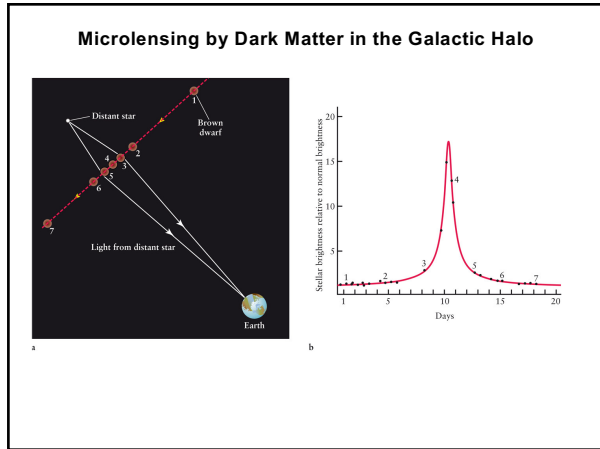
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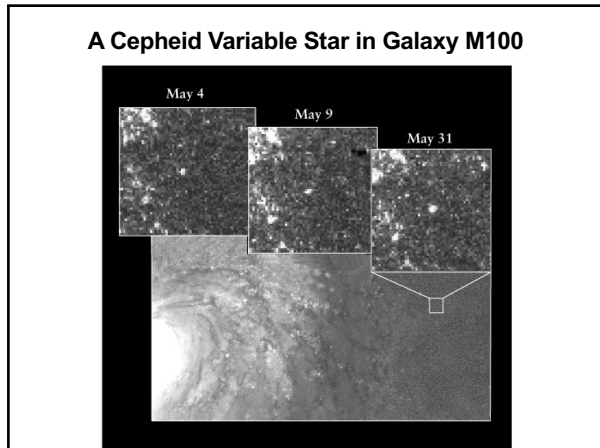
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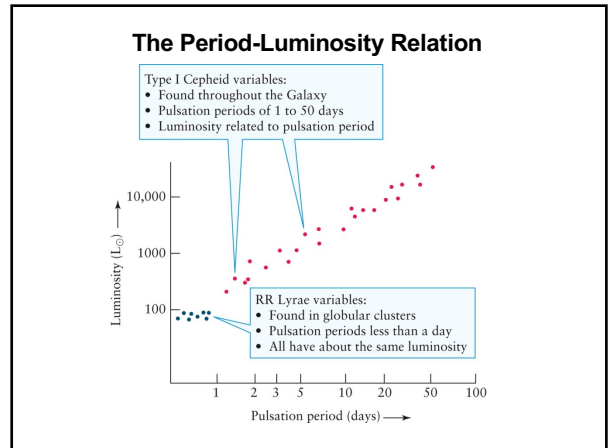
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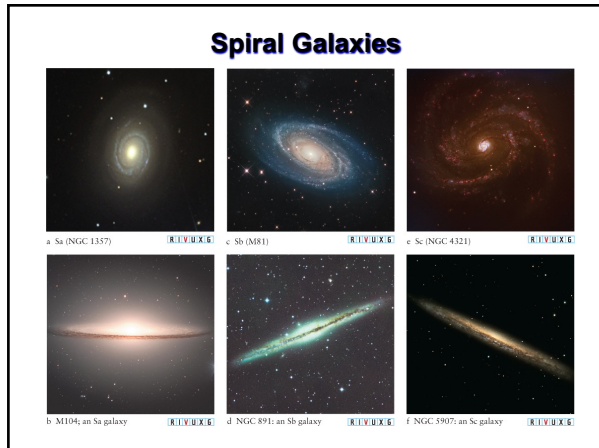
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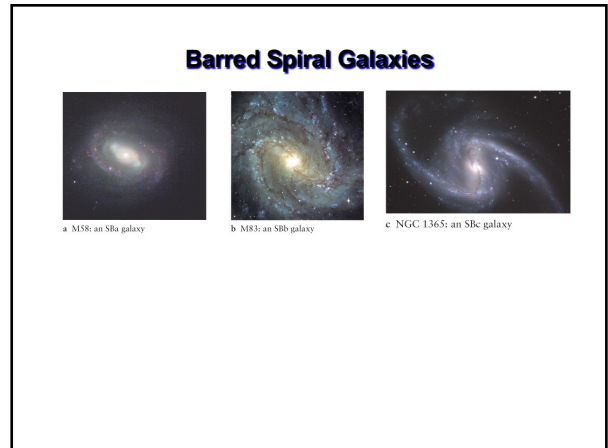
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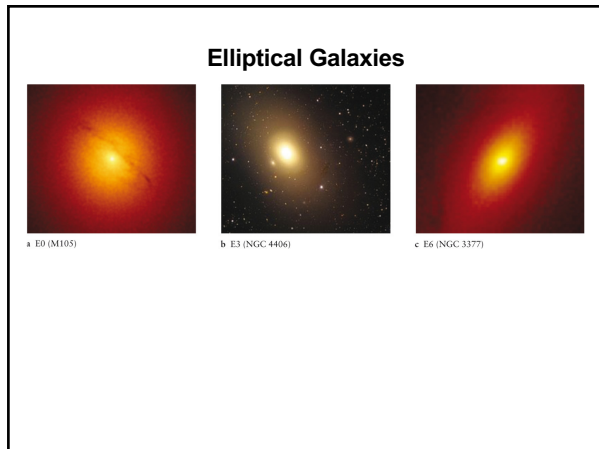
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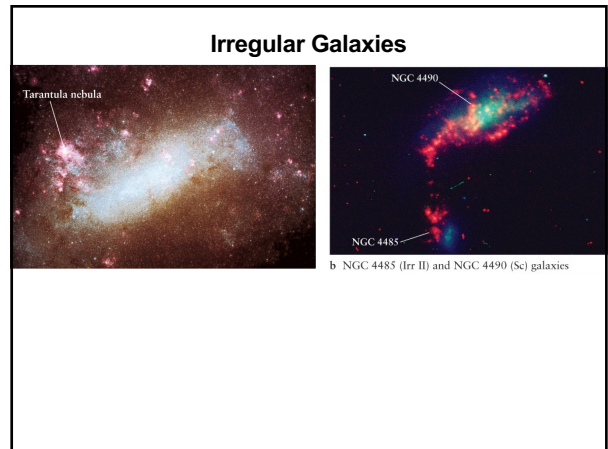
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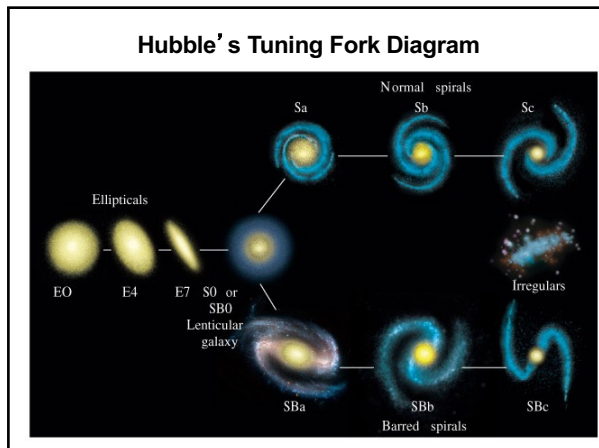
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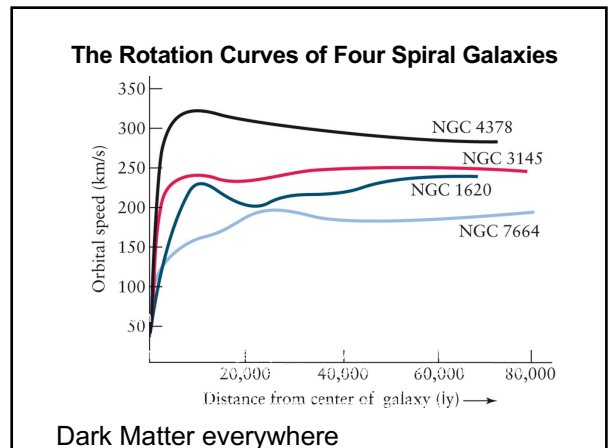
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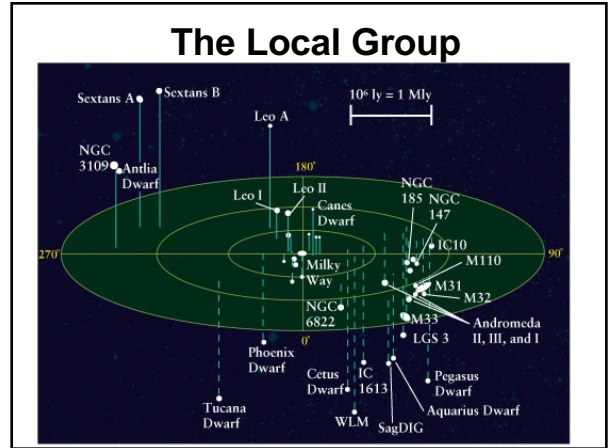
TABLE 12-1 Some Properties of Galaxies

	Spiral (S) and barred spiral (SB) galaxies	Elliptical galaxies (E)	Irregular galaxies (Irr)
Mass (M_{\odot})	10^7 to 4×10^{11}	10^7 to 10^{11}	10^6 to 3×10^{10}
Luminosity (L_{\odot})	10^6 to 2×10^{10}	10^7 to 10^{10}	10^6 to 10^9
Diameter (ly)	1.6×10^3 to 8×10^5	3×10^3 to 6.5×10^5	3×10^3 to 3×10^4
Stellar populations	Disk: young Population I central bulge; halo: Population II and old Population I	Population II and old Population I	Mostly Population I
Percentage of observed galaxies	77%	*20%	3%

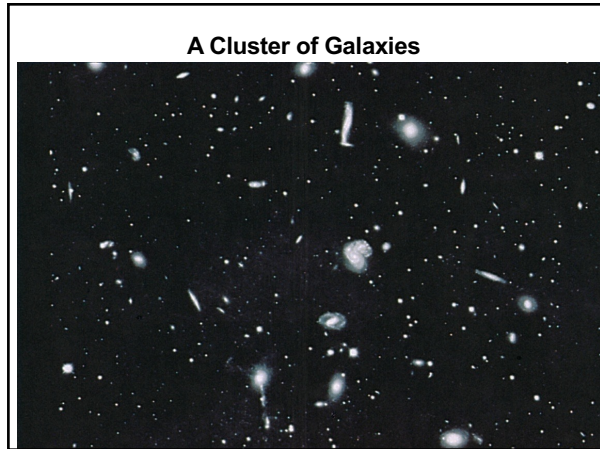
*This percentage does not include dwarf elliptical galaxies that are as yet too dim and distant to detect. Hence, the actual percentage of galaxies that are ellipticals is likely to be higher than shown here.

Population I: metal-rich stars
Population II: metal-poor stars

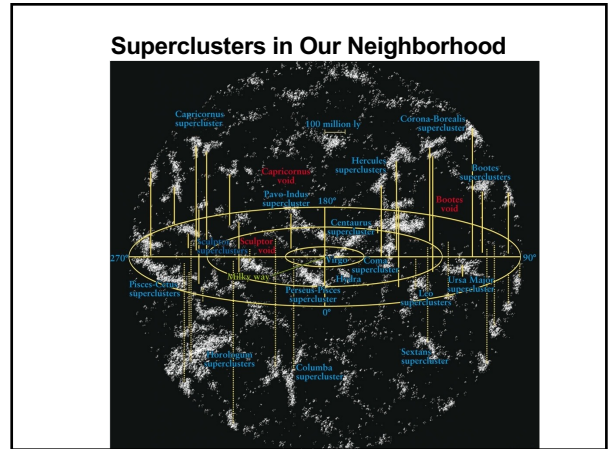
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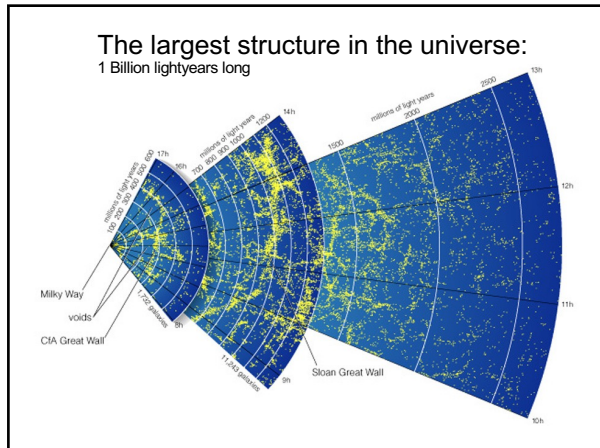
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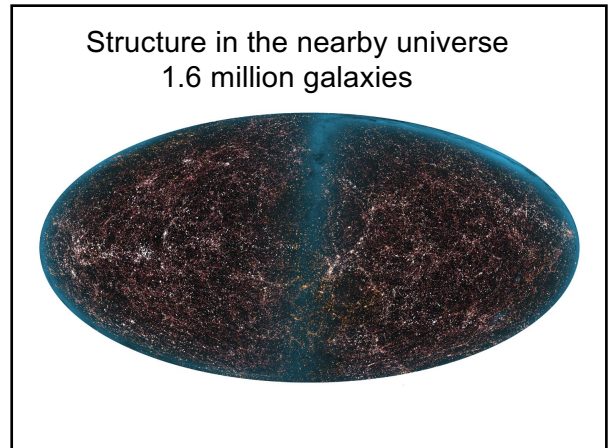
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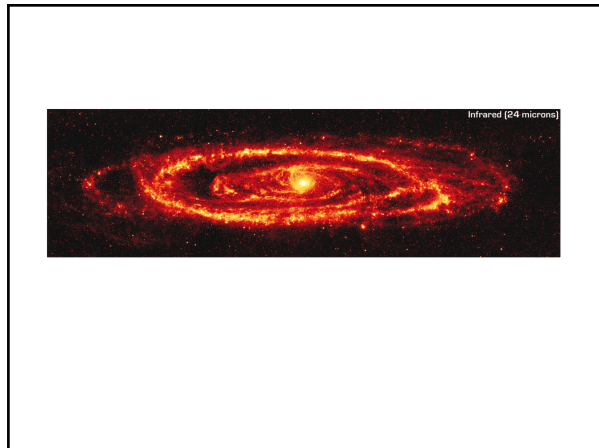
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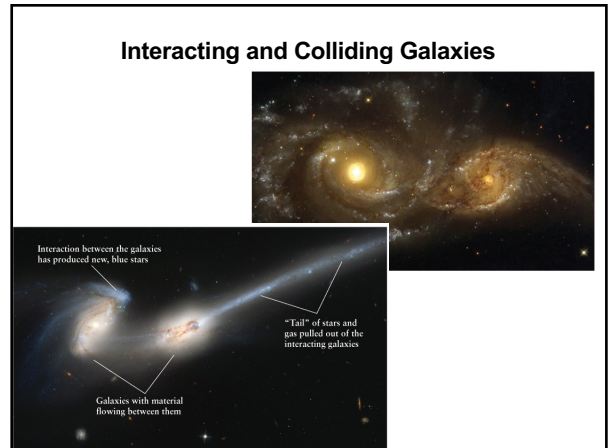
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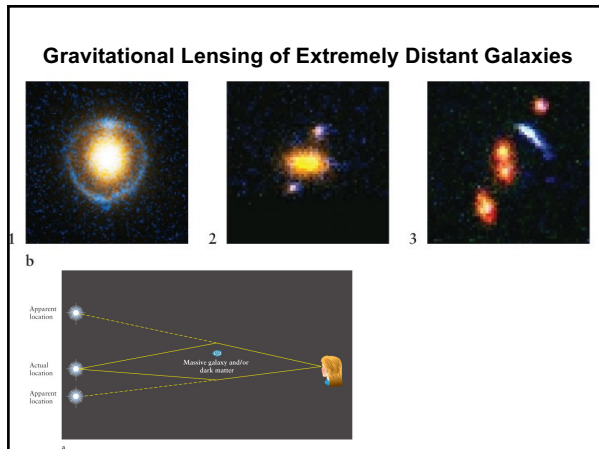
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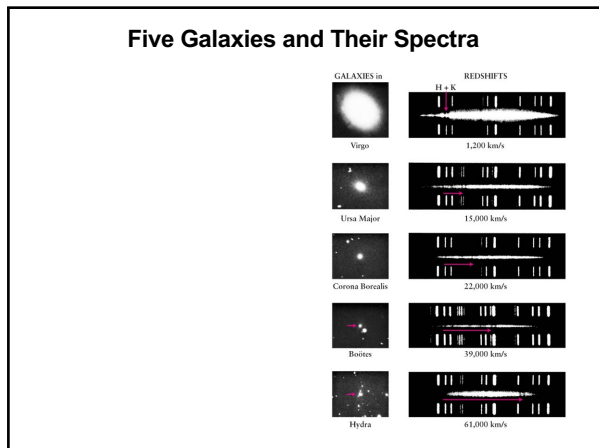
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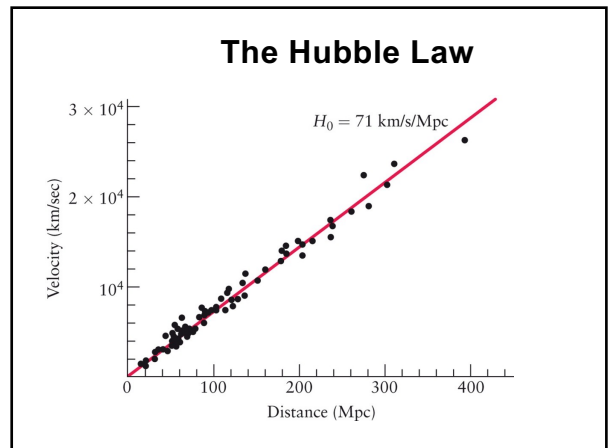
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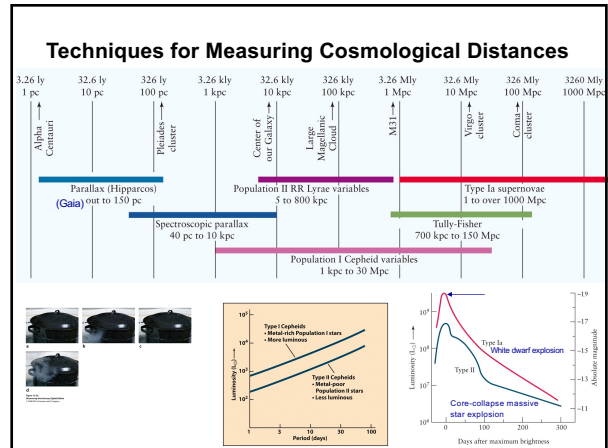


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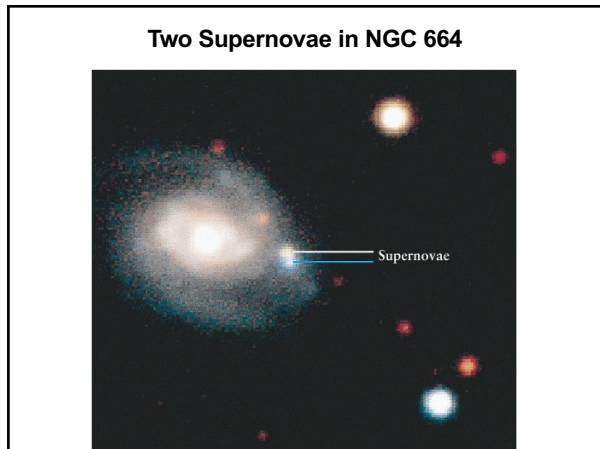
The Expanding universe and the Expanding Chocolate Chip Cake Analogy

The expanding universe can be compared to a chocolate chip cake baking and expanding in the International Space Station. Just as all of the chocolate chips move apart as the cake rises, all of the superclusters of galaxies recede from each other as the universe expands.

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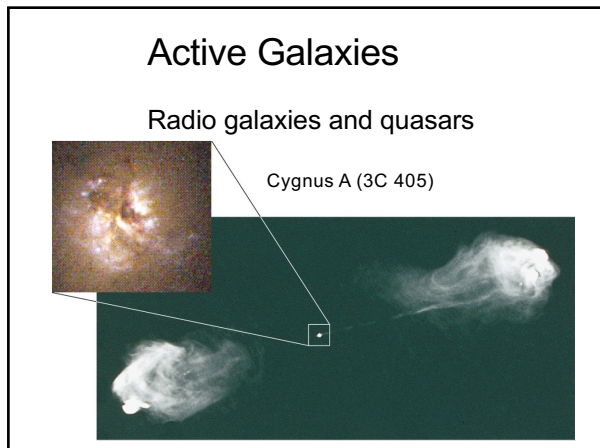


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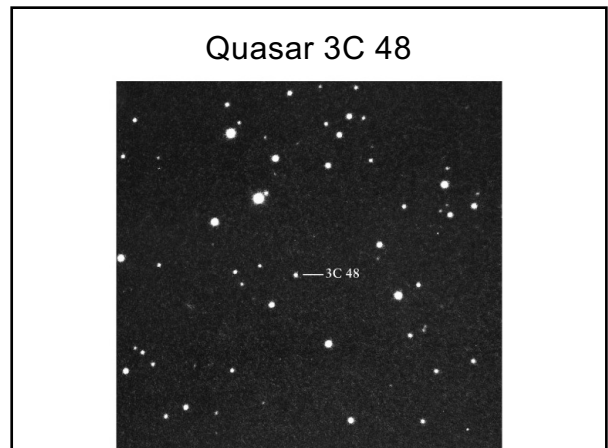
Distant Galaxies

(a) The young cluster of galaxies MS1054-03, shown on the left, contains many orbiting pairs of galaxies, as well as remnants of recent galaxy collisions. Several of these systems are shown at the right. This cluster is located 8 billion ly away from Earth. (b) The farthest known galaxy, shown in the lower-right inset, is 13.2 billion light-years from Earth. It is in the constellation Fornax, in the southern hemisphere.

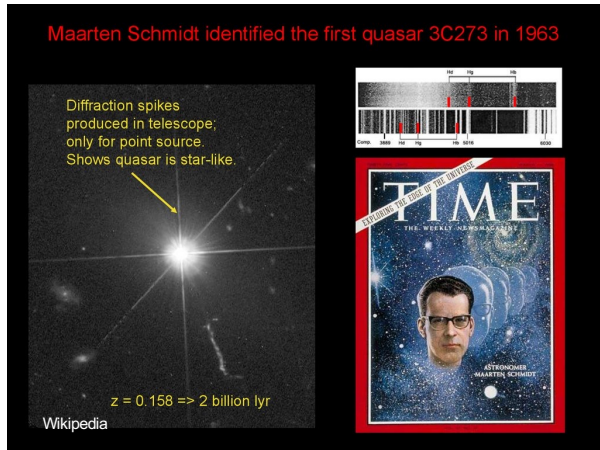
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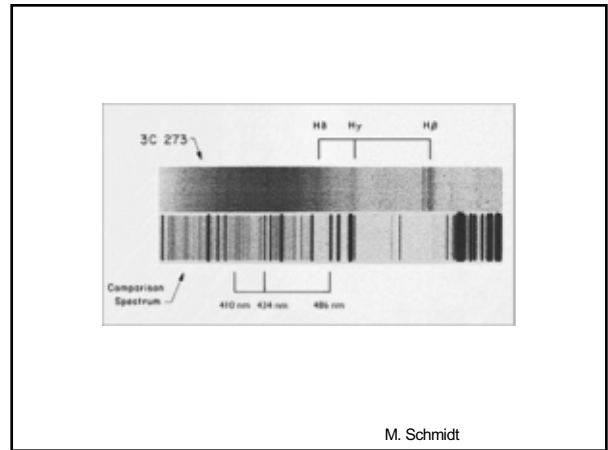
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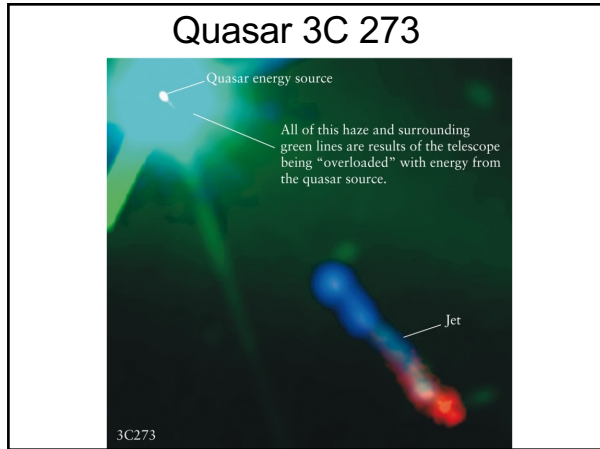
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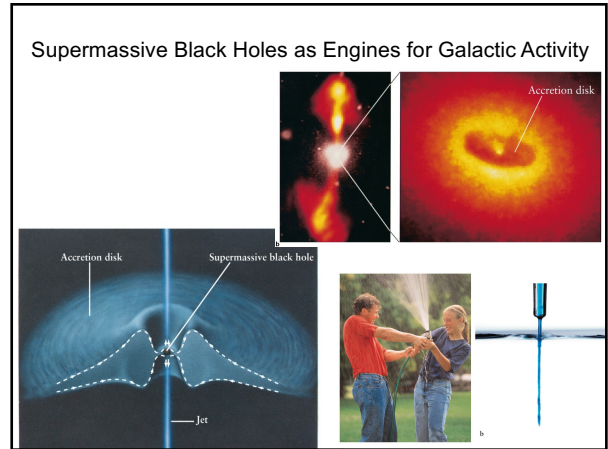
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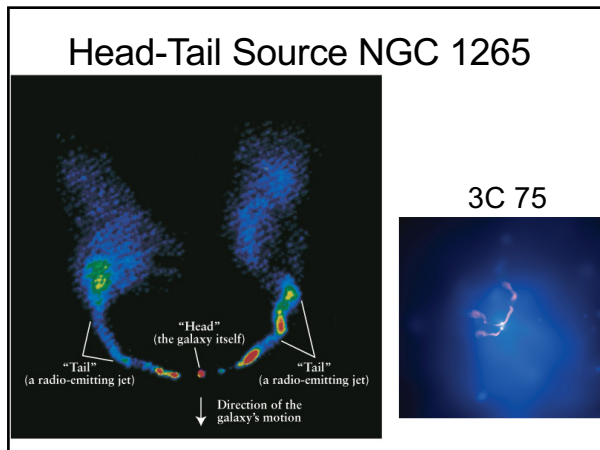
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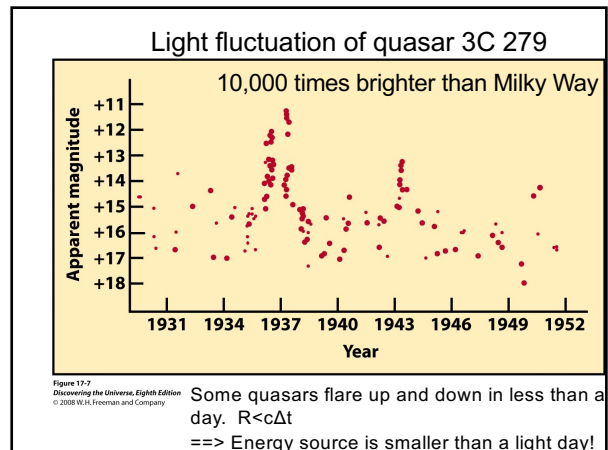
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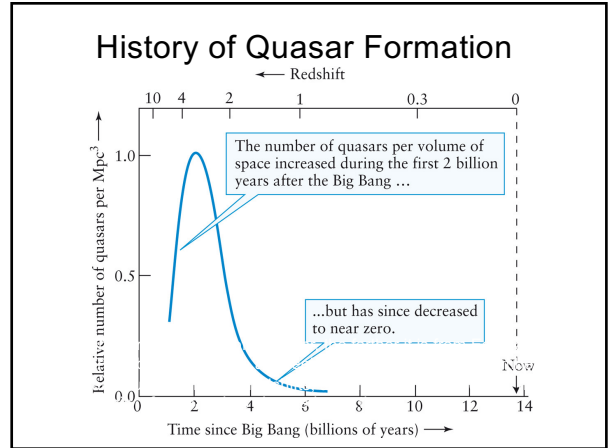


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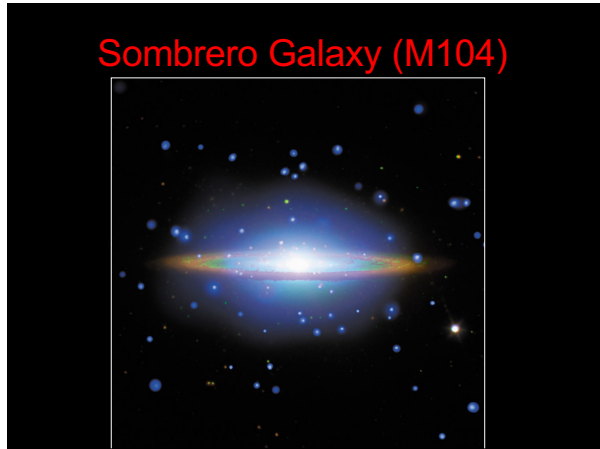
TABLE 12-2 Galaxy and Quasar Luminosities

Object	Luminosity (watts)
Sun	4×10^{26}
Milky Way Galaxy	10^{37}
Seyfert galaxies	$10^{36} - 10^{38}$
Radio galaxies	$10^{36} - 10^{38}$
Quasars	$10^{38} - 10^{42}$

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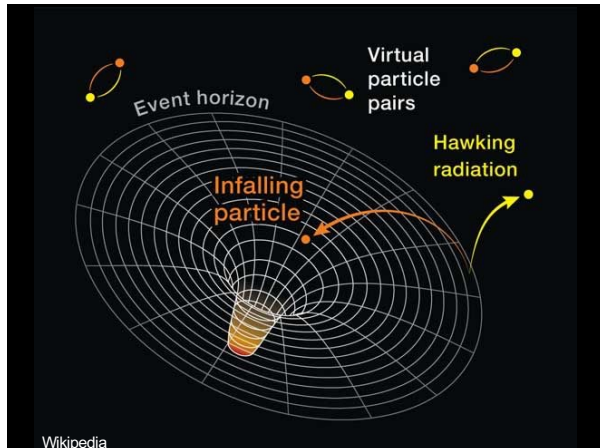
Hawking radiation

Black holes evaporate

The process happens because black holes can convert their mass into energy through virtual particle production in the vicinity of the event horizon.

Virtual particle pairs ($e^+ e^-$ or photon photon) appear and disappear within 10^{-21} s.

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Tidal forces could pull them apart where one Particle disappears beyond the event horizon and the other particle becomes real.

The particles that leave the vicinity of the black hole are called Hawking radiation.

The result is that black holes lose mass and evaporate.

The timescale of evaporation is for
 $M_{BH} = 5M_{sol} \rightarrow 10^{62}$ yr
 $M_{BH} = 10^{10} \text{kg} \rightarrow 15$ Bill yr

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